Title. Concern about falling is associated with segmental control when turning in older adults

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Abstract

Background: Healthy young adults typically exhibit a progressive 'top-down' reorientation of body segments (i.e., head, trunk, then pelvis) during turning. This behaviour is less evident in older adults at risk of falling, who often reduce angular displacement between body segments during turns. The potential functional and psychological contributors to this so-called 'en-bloc' turning strategy are not yet understood.

Research question: Are there associations between concern about falling and variables representing en-bloc turning (i.e., increased coupling between body segments)?

Methods: Twenty-one older adults were assessed while turning during an adaptive walking task. We collected data from markers forming the head, trunk, and pelvis segments, while gait velocity throughout the turn was calculated from a sternum marker. We correlated several variables with concern about falling alone, as well as while controlling for functional balance ability.

Results: Correlation analyses revealed that concern about falling was related to en-bloc turning strategies and slower gait velocity throughout the turn, when analysed independently of functional balance. When controlling for balance ability, en-bloc turning strategies between the head and trunk, as well as the head and pelvis, remained significantly associated with concern about falling.

Significance: Findings offer an insight into the potential role that psychological characteristics may have in determining older adults' turning behaviour and associated risk of falling.

Keywords

Falls efficacy; fear of falling; en-bloc; fall-risk; segmental coupling

1. Introduction

Falls by older adults (OAs) commonly occur during turning [1]. Such falls may arise, in part, due to rigid 'en-bloc' turning strategies, which could reduce reactive capabilities to perturbation [2]. We examine the contributions of functional balance and psychological factors when using such strategies.

The mechanics of turning typically follow a progressive top-down 'unfolding' pattern; beginning with the head, with subsequent rotational adaptations to the trunk then feet [3,4]. When turning 360° on the spot, OAs who subsequently fall display smaller angular differences from head to trunk and trunk to pelvis [2]. It remains unclear if this en-bloc strategy is associated with physiological constraints limiting decoupling between body segments (i.e., functional balance ability) or perceived balance ability (i.e., concern about falling).

Psychological factors, namely concern about falling, contribute to the use of cautious balance strategies in OAs [5]. It is reported that lower levels of balance confidence are correlated with cautious turning behaviour [4]. While researchers propose a link between concern about falling and en-bloc turning in OAs [6], this association has yet to be examined empirically. Initially, we explored how concerns about falling relate to turning behaviour, *independent* of functional balance. We hypothesised that en-bloc turning strategies are associated with greater concerns about falling. These associations were predicted to remain when controlling for functional balance.

2. Methods

2.1. Participants

Twenty-one healthy OAs (5 M/16 F; 73.95 ± 7.05 years) participated. Participants with neurological impairment, musculoskeletal diagnoses, or prescribed medication for anxiety or dizziness were excluded. Informed consent and ethical approval were obtained. See Table 1 for participant characteristics.

TABLE 1

2.2. Apparatus

We collected three-dimensional coordinates from reflective markers located on each temple (head), the acromio-clavicular joint of each shoulder (trunk), the xiphoid process of the sternum, and the anterior superior iliac spine (ASIS) of each hip (pelvis) (Fig. 1a) using an eight-camera Motion Analysis system (Santa Rosa, California, USA) sampling at 150 Hz.

2.3. Procedure

Participants walked along two nonlinear paths (Fig. 1b) comprising eleven white wooden blocks, with all other blocks painted black in a 6 × 5 grid. Each wooden block measured 0.4m × 0.4m, with a height of 0.3m. Participants walked (and turned) at a self-selected speed along the white path without contacting the black blocks. Two blocks per pattern were marked with crosses that acted as stepping targets to normalise foot placement with reference to the intended walking path. Only turns related to the first of these stepping targets were analysed (Fig. 1b).

Participants walked from behind a screen, up a ramp (1.2m in length), along the white path and down a corresponding ramp at the walkway end. Twelve trials (4 blocks of 3 walks) were completed. Walkway patterns were randomized.

FIGURE 1

2.4. Data Processing

We applied a low-pass (Butterworth) filter with a cut-off frequency of 5 Hz to all kinematic data. We analysed data between 0.55m prior to, and 0.4m to the lateral side (dependent on turn direction) of, the intersection point (Fig. 1b). Angular displacement profiles of each body segment (head, trunk, and pelvis) in the yaw plane were calculated, relative to the horizontal axis (Fig. 1b). First- (velocity), second- (acceleration) and third- (jerk) derivatives of the angular data were calculated to define turn onset/offset. Similarly to previous research [7], turn onset was defined as the point of a zero-crossing in the jerk profile and a corresponding negative to positive reversal in the acceleration profile prior to a continuous and sustained angular displacement above zero degrees. Turn offset was the point the angular velocity profile returned to, and remained below, zero. We removed trials containing instances of 'spin turns' [8], which were identified by visually inspecting kinematic data.

2.5. Measures

2.5.1. Maximum angular difference between segments

The absolute maximum difference (degrees) when one segment's angular trace was subtracted from another was calculated from head to trunk, trunk to pelvis, and head to pelvis.

2.5.2. Gait velocity through the turn

We calculated the instantaneous velocity (m/sec) of the sternum from the first derivative of the sternum marker. The mean velocity (m/sec) was calculated between turn onset/offset.

2.5.3. Concern about falling and functional balance

We employed the Falls Efficacy Scale-International (FES-I) [9] to assess concern about falling and the Berg Balance Scale (BBS) [10] to evaluate functional balance.

2.6 Statistical Analysis

We conducted correlation analyses to determine the relationship between concern about falling (FES-I) and turning measures. As the maximum angular difference between head and trunk segments violated parametric assumptions, Spearman's correlational analyses were employed to examine associations with this variable. Pearson's correlations were conducted for all other variables. Partial correlation analyses were conducted to assess associations between FES-I and turning measures, when controlling for BBS. Non-parametric correlations were used as BBS scores violated parametric assumptions. We report one-tailed *p*-values.

3. Results

Higher levels of concern about falling (FES-I) were associated with reduced maximum angular difference between the head and trunk (r_s = -.45, p = .02) and head and pelvis (r = -.65, p = .001). Higher levels of concern were associated with lower velocity through the turn (r = -.63, p = .001). When controlling for BBS, there remained significant associations between FES-I and maximum angular difference for the head and trunk (r_s = -.38, p = .049) and head and pelvis (r_s = -.39, p = .043). Results are presented in Table 2.

TABLE 2

4. Discussion

We examined the relationships between concern about falling, functional balance, and turning characteristics in OAs performing an adaptive walking task. The overall turn velocity was not associated with concern about falling, when controlling for functional balance, while decoupling between the head and trunk/pelvis was significantly correlated. The absence of any significant relationship between concern about falling and trunk-pelvis decoupling indicates that head-pelvis decoupling is largely independent of the decoupling between head and trunk in concerned participants. Such rigidity between upper-body segments indicates self-preservation behaviours to minimise instability. Our findings support interpretations linking turning caution with reduced balance confidence in OA [4].

Concern about falling is associated with increased self-reported conscious processing of gait [11]. The concept of freezing degrees of freedom, commonly observed during postural threat in OAs, is thought to arise through a re-investment in conscious control [12]. Concern about falling leads to a decrease in fixations and an increase in fixation durations during adaptive gait in OAs, implying that these behaviours help stabilise the head and visual scene [12]. Similarly, concerned OAs have been shown to adopt a ‘head stabilisation’ strategy during walking, reducing the amplitude of head oscillations [13]. We suggest current findings indicate that these stabilisation strategies can be extended to the concept of head-trunk decoupling during self-paced turning.

In non-concerned individuals, increased angular displacement between head and trunk permits a decoupling of the egocentric frame of reference for both segments (i.e., the head, and corresponding visual input, assumes a new direction, while the trunk and pelvis remain aligned in the previous heading direction) [14,15]. Our results suggest that en-bloc coupling between head and trunk may represent an attempt to reduce these demands in concerned OAs. Further work is necessary to scrutinise the causal nature of these relationships and the impact of changes in attentional and cognitive factors (e.g., conscious movement processing) on gait stability and fall-risk.

4.1 Limitations

While the pre-defined path used in the present research potentially constrained participants' movement, it was deemed appropriate to maintain experimental control. The paths were also designed to provide an indication of real-world pre-defined turning (e.g., turning to enter a doorway from a hall). Also, differences in body segment co-ordination could have been calculated by an alternative method (e.g., delay in onset of reorientation [16]). Furthermore, spin turns were identified and removed by visually inspecting kinematic data, rather than through computational means.

4.2 Conclusions

This research demonstrates associations between concern about falling and en-bloc turning strategies in older adults when controlling for functional balance, thereby, offering insight into the role psychological factors may play in the risk of falling in this population. Future work should seek to evaluate the associations reported here in a larger sample, as well as during experimentally-manipulated conditions of concern about falling.

Declaration of Competing Interest

None.

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List of Figures and Tables

Figure 1

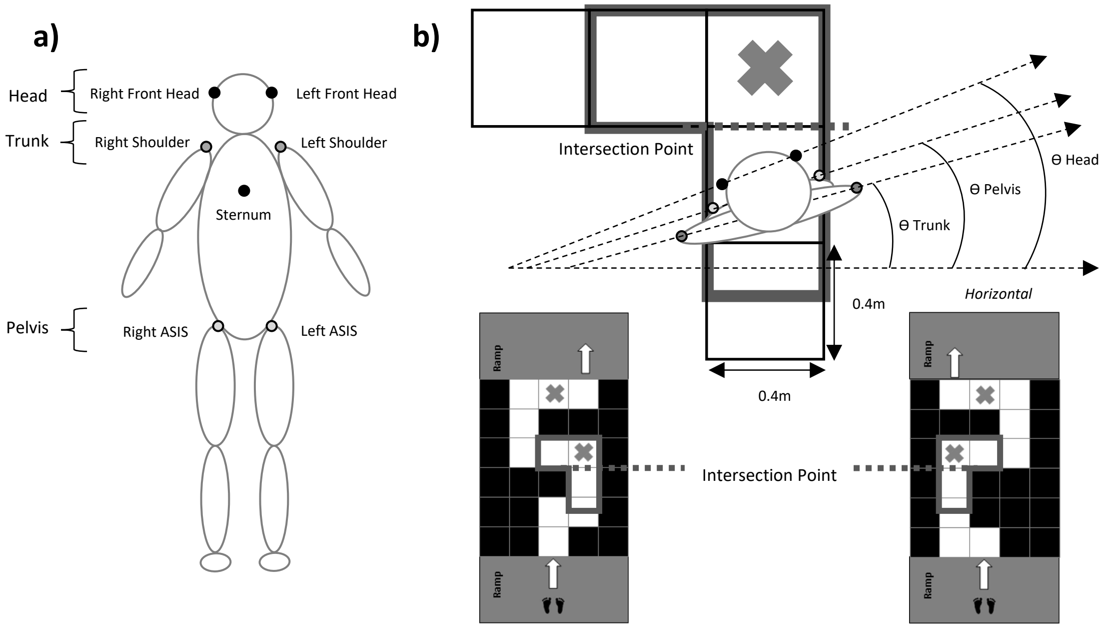
a)
Head
Right Front Head
Left Front Head
Trunk
Right Shoulder
Left Shoulder
Sternum
Pelvis
Right ASIS
Left ASIS
b)
Intersection Point
Θ Head
Θ Pelvis
Θ Trunk
Horizontal
0.4m
0.4m
Ramp
Intersection Point
Ramp
Ramp
Ramp

Table 1

Measure: mean (standard deviation)	Participants (*N* = 21)
Age (years)	73.95 (± 7.05)
Height (cm)	163.61 (± 7.78)
Weight (kg)	80.53 (± 15.11)
Number of fallers[a]	7/21
Berg Balance Scale (0-56)	52.19 (± 3.68)
Montreal Cognitive Assessment (0-30)	26.48 (± 1.97)
Falls Efficacy Scale - International (16-64)	26.71 (± 8.14)
Max. Angular Difference between Head and Trunk (degrees)	12.71 (± 4.34)
Max. Angular Difference between Trunk and Pelvis (degrees)	7.61 (± 2.84)
Max. Angular Difference between Head and Pelvis (degrees)	15.59 (± 4.25)
Gait Velocity Through Turn (m/sec)	0.52 (± 0.12)

Table 2

		Max. Angular difference between Head and Trunk	Max. Angular difference between Trunk and Pelvis	Max. Angular difference between Head and Pelvis	Velocity Through the Turn
Concern about Falling	*r* =	-.450[†]	-.272	-.653	-.626
	p =	.020	.116	.001	.001
Concern about Falling (when controlling for Functional Balance)	r_s =	-.380	.137	-.394	-.287
	p =	.049	.283	.043	.110

Note: Concern about falling was assessed through the Falls Efficacy Scale-International; where higher scores indicate greater concerns about falling. Functional balance was assessed through the Berg Balance Scale. Given the clear directional hypotheses, one-tailed *p*-values are reported for all. [†] r_s value reported, as a Spearman's correlation was conducted.